JX-ISAS-SUZAKU-MEMO-2008-01
Title: Reproducibility of the HXD-GSO Non X-ray Background for the ver 2.0 processing data
Category: HXD
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Date: 2008-01-09

Reproducibility of the HXD-GSO Non X-ray Background for the ver 2.0 processing data

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January 09, 2008

1 Introduction

The GSO/BGO phoswich configuration of HXD (Hard X-ray Detector) scintillation detectors is designed to reduce an instrumental background as much as possible (Takahashi et al. 2007), and achieves an unprecedented low background in the energy ranges of 150-500 keV (Kokubun et al. 2007). This low background enables us to study the spectral shape and time variability accurately around several 100 keV. A limiting factor for the sensitivity of the HXD-GSO is a reproducibility in the background estimation, rather than the statistical error.

Following the start of the ver 2.0 pipeline processing, the GSO background model has been updated. The modeling method is basically the same as that of the background for the ver 1.2 processing (Fukazawa et al. SUZAKU-MEMO 2007-02), but some minor revisions are included; several bugs were fixed and the model function was improved a bit. Since the background modeling needs a correct GSO gain correction, the GSO background model can be generated only after the creation of the GSO gain history file, which is usually released at the beginning of each month. Therefore, the GSO background model is released 1–2 months after the release of the real observational data. Note that users should reprocess the GSO data by `hxdpi` and `hxdgrade` with the correct GSO gain history file, before subtracting the background model.

Here we examine the background reproducibility of the HXD-GSO for the ver 2.0 pipeline processing, mainly by comparing the background model prediction and the data during the earth occultation. Since the earth is known to be dark in hard X-rays and soft gamma-rays, the earth occultation data can be regarded as the Non X-ray Background (NXB) for the HXD. Comparison with the blank sky data, where the GSO signal from celestial objects are thought to be negligible, is also performed. In the report, we analyze the data with the same criterion of the default clean event, except for the cut-off rigidity (COR) of > 8 GV [1]. Furthermore, we discard the period when the total GSO count rate is less than 15 c/s. Such a low count rate occurs when only 1/4 of GSO data are output to the telemetry for reducing the data size, usually during the data rate L (usually during SAA, low COR period, or earth occultation). However, this 1/4 mode sometimes continues even in the data rate M/H/SH, and becomes contained in the clean event.

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[1] COR selection of the default clean event is > 6 GV.

The background model does not support such a mode. Users are also strongly recommended to check whether a period of such a low count rate exists or not in their data by looking at light curves, and if it exists, it should be discarded.

2 Comparison with the Earth Occultation Data

In this section, we examine the reproducibility of the HXD-GSO NXB by utilizing the available earth occultation data in 2005 Aug 17 to 2007 Aug 31. The observational mode of the GSO has been changed twice on 2006 March 23 and May 13; the lower discrimination level and pulse-shape discrimination level were changed. The BGD model is produced by considering these two mode changes (see Fukazawa et al. 2007 in detail). In figure 1 left, the GSO count rate (50–200 keV) of the NXB during earth occulation data is plotted. Due to the activation during the SAA passage, the count rate gradually increases and are reaching saturation. Figure 1 right shows the comparison of spectra of earth occulation data in different epochs. Gradual increase of several activation-induced lines are clearly seen. The background model should consider this increase.

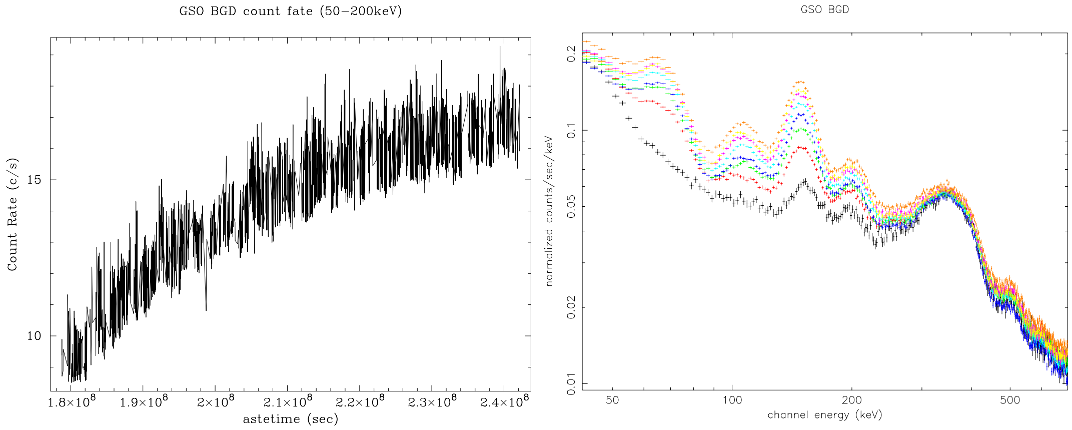


Figure 1: (left) Time history of the GSO count rate (50–200 keV) of NXB during earth occulation data. (right) Comparison of spectra of earth occulation data in different epochs; 2005-08-31, 2005-12-03, 2006-03-09, 2006-06-13, 2006-09-26, 2007-01-05, 2007-04-10, and 2007-08-09 from bottom to top.

In Figure 2, we compared the NXB count rates between the earth occultation data and the background model in 50–100 keV and 100–200 keV range, against the elapsed day after the Suzaku launch. The data and background are accumulated within the same GTI. Each observation is divided into several periods during which the exposure is 10 ks. When the exposure of earth occultation within one observation is less than 10 ks, we do not use the data. Accordingly, the GSO count in each data set is typically $(4-9)\times 10^4$, and thus the statistical error is typically 0.3–0.5 %.

Most of the data and model agree in ~ 2 %, and no significant difference in reproducibility is seen between models even in the period of 2006 March 23 to May 13. Figure 3 plots the distribution of the NXB count rate ratio between the data and the model prediction. In both energy band, the distribution is well represented by a Gaussian with σ of 0.754 % and 0.691 % in the 50–100 keV and 100–200 keV band, respectively. Considering the average of statistical error of 0.396 % and 0.356 %, the 1σ systematic error is estimated to be 0.64 % and 0.59 % in the 50–100 keV and 100–200 keV band, respectively. Note that the systematic error depends on the event selection criteria (e.g. COR and energy band) and the integration time. Therefore it

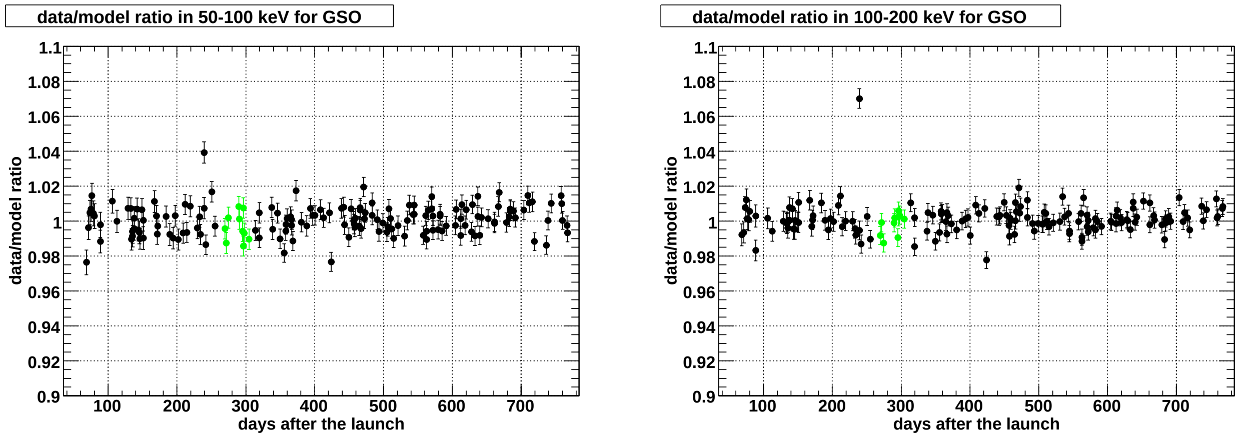


Figure 2: (left) A comparison of the NXB count rate in the earth occultation in 50–100 keV between the data and the model prediction. Data from 2006 March 23 to May 13 are shown by green crosses (see text). (right) The same plot but for 100–200 keV.

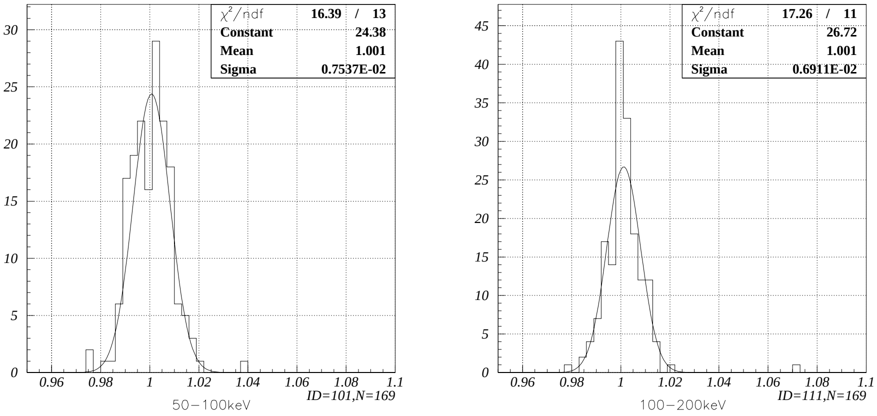


Figure 3: (left) Distribution of the NXB count rate ratio between the data and the model prediction in the 50–100 keV band. (right) The same plot but for the 100–200 keV band.

is recommended that users estimate the systematic error by themselves; e.g. by comparing light curves and spectra between the earth occultation data and background model, filtered with the same selection criteria., and making the plot like figure 2 and 3. Earth occultation data just before/after your observation are also useful, and they are available as a trend archive. Note that users do not forget to reprocess the event data of trend archive by the latest `hxdpi` and `hxdgrade`. There are some data points, which significantly deviate from 1.0 by >2%, and see §5 in detail.

Figure 4 shows the comparison of the spectra for earth data and background model, summed over 88 observations of dark objects (see table 1). The total exposure is 923 ks. It can be seen that the data and model well agree with each other in all the energy band within 1%.

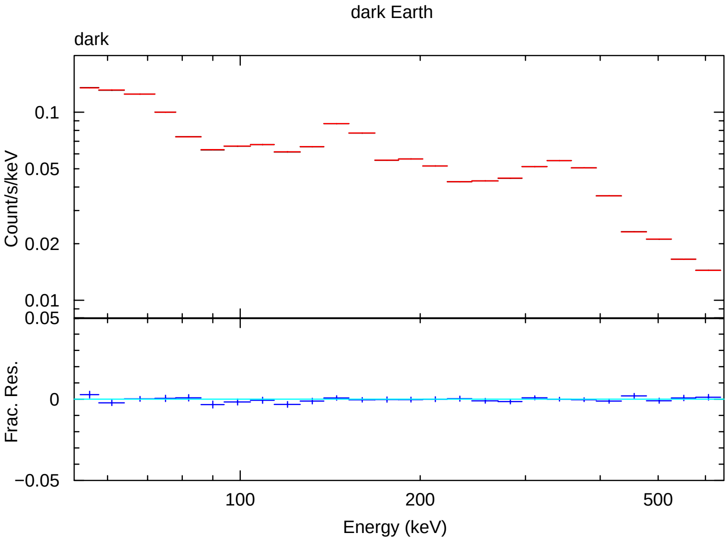


Figure 4: Comparison of the spectra for earth data and background model, summed over 88 observations of dark objects. Black, red, and blue represents the earth data, background model, and fractional residual, respectively.

Table 1: List of dark objects analyzed in this report. See the following web page for observation date and data sequence number.

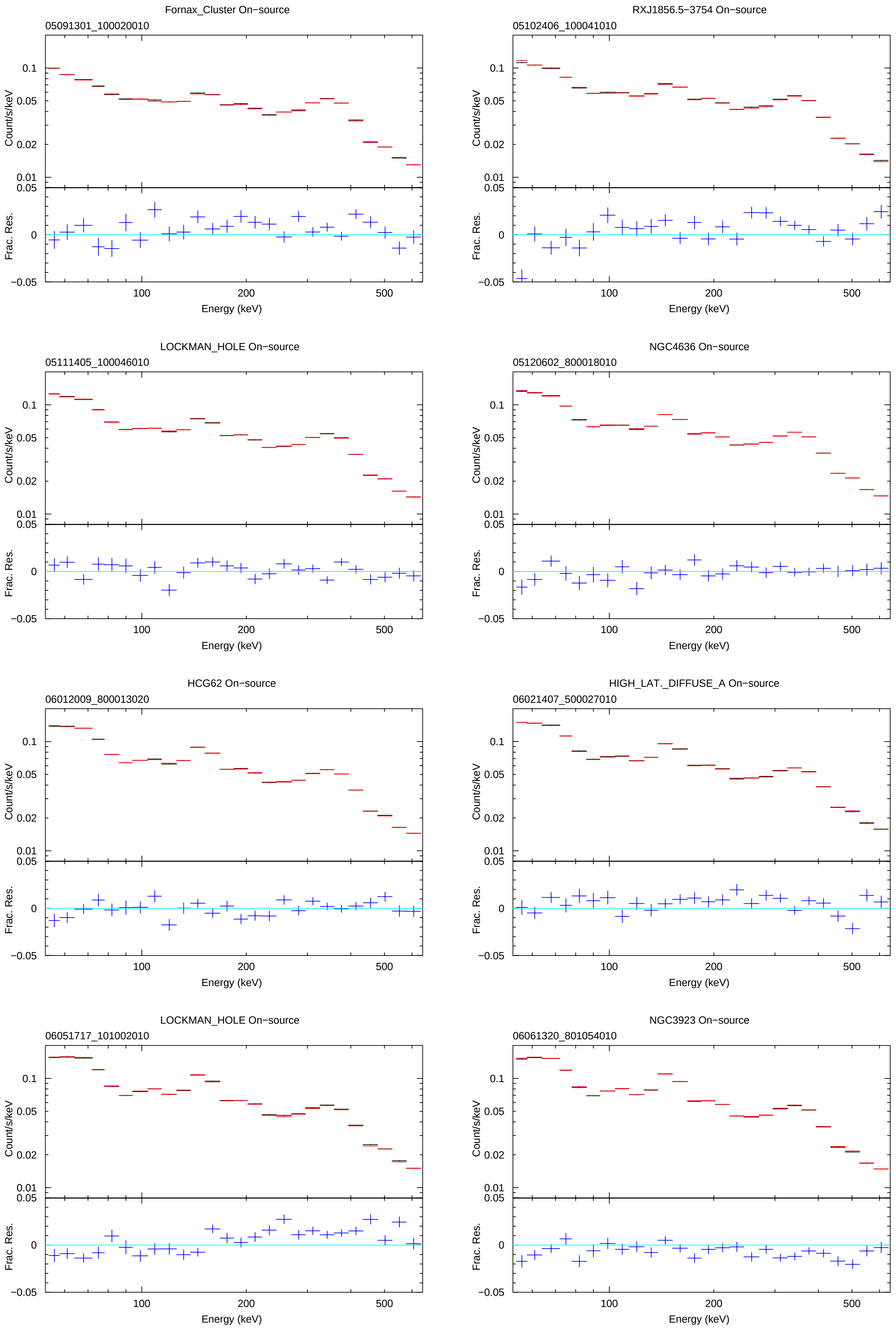
`http://darts.isas.jaxa.jp/astro/tables/SUZAKU_LOG.html`

SN1006_NE-Rim	SN1006_SW-Rim	SN1006_SW_BG	
BD+30.3639	RXJ_1713-3946_BGD1	A2218	A2218_offset
NORTH_POLAR_SPUR	ABELL_3376	ULXs_in_NGC_1313	RXJ1856.5-3754
AE_AQUARII	BD+30.3639	A3376_WEST_RELIC	A1060_OFFSET
A1060	CYGNUS_LOOP_NE1	CYGNUS_LOOP_NE2	PG1211+143
A2801	A2811	A2811_OFFSET	CYGNUS_LOOP_NE3
CYGNUS_LOOP_NE4	A2804	1H0707-495	NGC4636
A1795_NearSouth	A1795_FarSouth	E0102-72	GRB060105
ARP220	Fornax_Cluster_North-Part2	A2052_+7-7	E0102-72
MBM12_Off-Cloud	NEP	HIGH_LAT._DIFFUSE_A	Jupiter1
Jupiter2	Jupiter3	Jupiter4	BULGE_3
BULGE_6	VICINITY_OF_LMC_X-3	DRACO_HVC-A	DRACO_HVC-B
G11.2-0.3	F05189-2524	IRAS08572+3915	SERSIC_159-03
CYGNUS_LOOP_P12	CYGNUS_LOOP_P13	MONOGEM_RING_WEST	BETA_LYRA-2
CYGNUS_LOOP_P14	CYGNUS_LOOP_P8	73P_SW3-Part2-C1	73P_SW3-Part2-C2
73P_SW3-Part2-C3	73P_SW3-Part2-C4	73P_SW3-Part2-C6	73P_SW3-Part2-C7
73P_SW3-Part2-C8	LOCKMAN_HOLE	CYGNUS_LOOP_P16	CYGNUS_LOOP_P17
CYGNUS_LOOP-3	CYGNUS_LOOP-4	73P-SW-1	73P-SW-2
73P-SW-3	73P-SW-4	73P-SW-5	73P-SW-6
73P-SW-7	73P-SW-8	73P-SW-9	73P-SW-10
73P-SW-12	73P-SW-13	73P-SW-14	73P-SW-15
GB1428+4217	NGC3923	SNR_G93.3+6.9-S4	TYCHO_SNR_HXD_BKGD
RXJ1347.5-1145-1			

3 Comparison with the Data of Dark Objects

In this section, we compared the NXB model with the on-source data of dark objects, whose signal is expected to be negligible for the HXD-GSO. Examples of comparison of spectra for 8 dark objects are summarized in Figure 5. Unlike the PIN, the CXB is negligible in the GSO band. No systematic difference is seen between the data and BGD model spectra, indicating that the background model is applicable for sky observations. We also compared the data and the NXB model light curves as summarized in figure 6 for the 50–100 keV band with a time bin of 4000 sec. Residuals are mostly within 2 % of the total count rate, and we see some modulations of a peak-to-peak amplitude up to ~ 0.1 c s^{-1} in a cycle of ~ 1 day.

Figure 7 shows the comparison of the spectra for on-source data and background model, summed over 88 observations of dark objects (see table 1). The exposure is 2430 ks. It can be seen that the data and model well agree with each other in all the energy band within 1 %.


Fornax_Cluster On−source
05091301_100020010

RXJ1856.5−3754 On−source
05102406_100041010

LOCKMAN_HOLE On−source
05111405_100046010

NGC4636 On−source
05120602_800018010

HCG62 On−source
06012009_800013020

HIGH_LAT._DIFFUSE_A On−source
06021407_500027010

LOCKMAN_HOLE On−source
06051717_101002010

NGC3923 On−source
06061320_801054010

Figure 5: Comparison of spectra between the data (black) and BGD model (red) for observations of objects with no known strong hard X-rays. Fractional residuals are given by blue crosses.

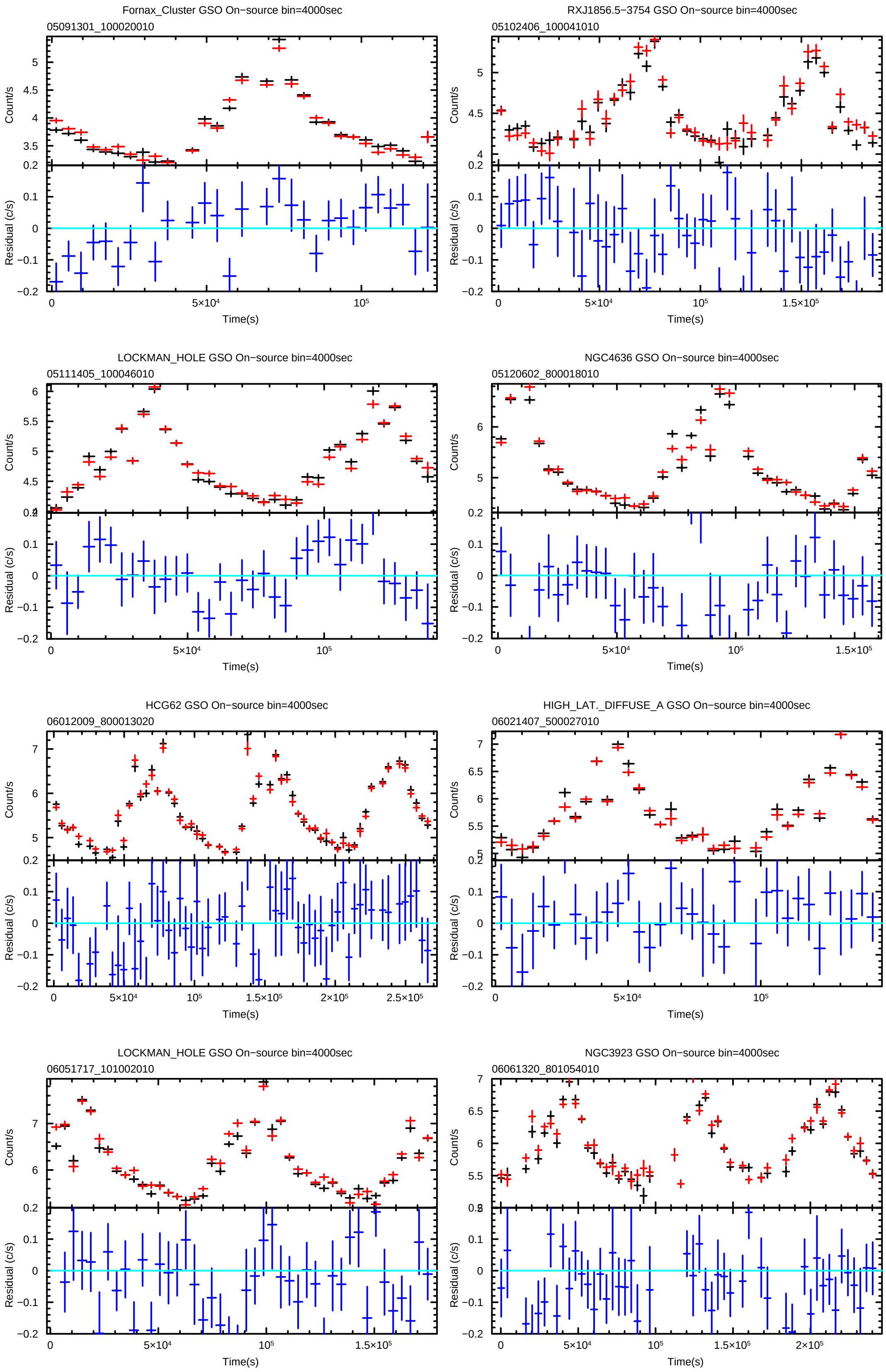


Figure 6: The same as figure 5 but for 50–100 keV light curves instead of spectra. In each panel, the upper figure shows the light curve and the lower figure shows the residuals. A time bin is 4000 sec.

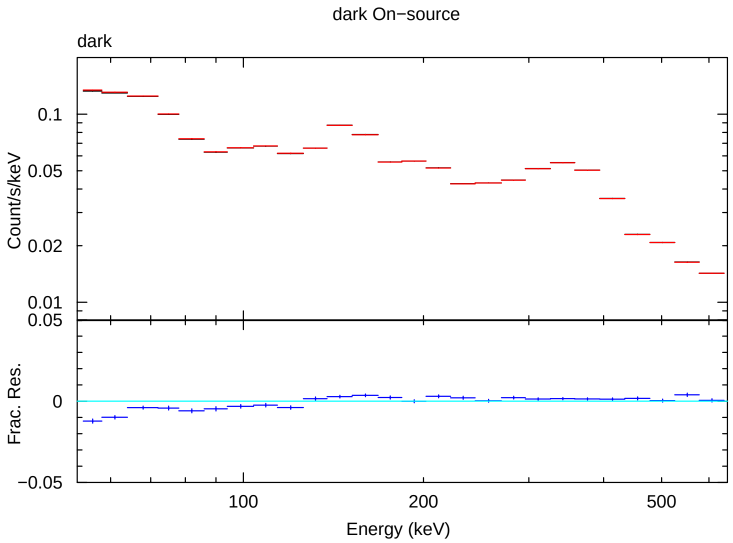


Figure 7: Comparison of the spectra for on-source data and background model, summed over 88 observations of dark objects. Black, red, and blue represents the earth data, background model, and fractional residual, respectively.

4 Note on studies of the BGD systematic uncertainty

It is very useful to look at the light curve of the GSO count rate for studying the BGD systematic error. Figure 8 shows the GSO 70–100 keV light curve from 2006 Mar. 12 to 2006 Mar. 30. Data of both on-source and earth-occultation are plotted as different colors. Together with the light curve of a shorter time scale in figure 6, it can be seen that the BGD systematic uncertainty is composed of two components; one with a shorter time scale within 1 day and another with a longer time scale of >1 day. The latter uncertainty appears as a modulation with a time scale of several days in the residual light curve, and its behavior is common between on-source and earth data. Accordingly, by studying the light curve as above, users can estimate the background level more accurately than by simply subtracting the background model. Note that the systematic error depends on the energy band, and thus users are recommended to create a similar light curve in the energy band that they are interested in.

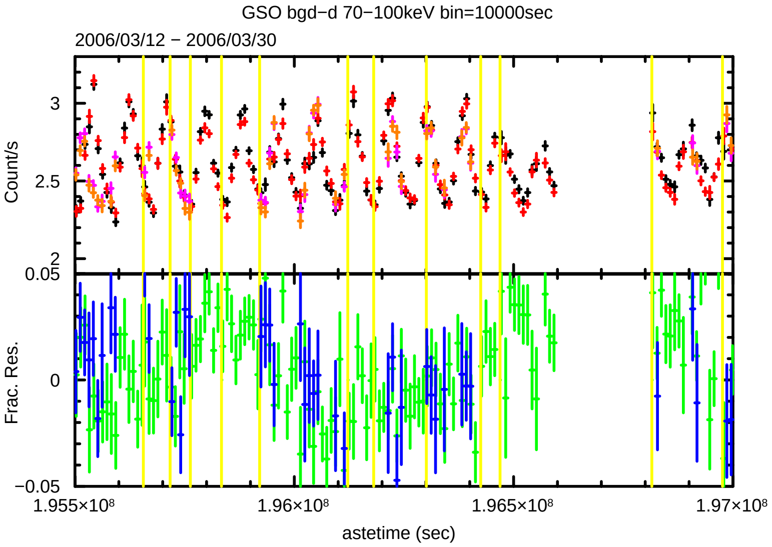


Figure 8: GSO light curve in 70–100 keV band. Black and red represent the count rate of on-source data and background model; brown and pink do that of earth data and background model, respectively. Green and blue in the bottom panel show the residual count rate of the on-source and earth, respectively. Vertical yellow lines represent the boundary of each observation.

5 Some Cautions

In figure 2, there are some data points, which significantly deviate from 1.0 by >2 %. Such data points correspond to the observation during which the HXD observation mode changed. Such operations were performed during the earth occultation for calibration or during on-source observations when the PIN became noisy. See `http://www.astro.isas.jaxa.jp/suzaku/log/hxd/` for checking whether your observation includes these operations or not. Since the GSO background model utilizes the count rate of the PIN Upper Discriminator, the operation relevant to the PIN affects the GSO background model. Also the period of 1/4 GSO data mode in the clean event, if it exists, should be discarded, as described in §1.

Correct gain calibration is important to estimate the background accurately, but it has been found that the GSO gain correction by the current `hxdpi` shows small discontinuity around 2006 Mar. 03 – 2006 May 09; energy scale of reprocessed data becomes different by several % from that of response and background. HXD team is now developing the new version `hxdpi` so as to resolve this problem.

Reference

- Takahashi T. et al. 2007, PASJ 59, S35
- Kokubun M. et al. 2007, PASJ 59, S53
- Fukazawa Y. et al., Suzaku Memo 2007-02